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CONTENTS.

	Page.
Soil Acidity and the use of Lime on Tea Soils ...	1
The Field Experiments at Tocklai	12
Meteorological Observations in Assam, 1924 ...	25
Some Observations on Stem Diseases in Cachar ...	37

SOIL ACIDITY AND THE USE OF LIME ON TEA SOILS.

BY

P. H. CARPENTER, H. R. COOPER, AND C. R. HARLER.

Lime is a necessary plant food, but practically all soils contain sufficient lime to supply the needs of plants for lime as food.

When lime is used in agriculture it is applied for the purpose of reducing the acidity* of over-acid soils. If it is applied in excess, the soil is then said to be alkaline. An alkaline soil will turn red litmus blue, while an acid soil will turn blue litmus red. If just sufficient lime is added to an acid soil so that it will not redden blue litmus, nor turn red litmus blue, but changes either to a purple colour, then it is said to be neutral.

Most farm crops do best on soils which are only slightly acid. When soil acidity is excessive the soil is said to be "sour," a condition readily recognised by practical farmers, for example on grazing land from the disappearance of clover and appearance of sorrel, and on arable land by the appearance of the disease known as "finger and toe" in turnips. In such cases the land may be made "sweet" again by liming. Even if an excess of lime is applied so that the soil becomes neutral or faintly alkaline, it is still better for most crops than an over-acid soil. In general therefore farms on acid soils are improved by liming, and the condition of soil acidity has been associated with the need of the soil for lime.

When it became known that lime favoured nitrification, that is, the formation of soluble plant food from crude insoluble

N. B.—The term acidity in reference to soil is used very loosely and is made to cover several phenomena such as the amount of lime that a soil can absorb and also the actual acidity in the soil or what might be called the intensity of the acidity in the soil. In this paper the reference is more particularly to the actual acidity of the soil rather than to its time requirement.

organic matter, the general need for lime on all acid soils came to be considered an established fact.

The enormous majority of Indian tea soils are exceedingly low in lime, and when samples are submitted to British analysts this fact has always been (and still is !) very strongly emphasised, and the use of lime has been advised. Mann, however, in spite of general home experience gives his opinion very definitely that tea soils in general do not need lime. In fact he expresses his conviction that : " The presence of more than a very small quantity of lime must always be regarded as evidence of unsuitability of the land (for tea)," and he also writes : " Small as the percentage (of lime) usually is in Assam soil, I think there is hardly any case where lime manuring is necessary because the soil is exhausted of this constituent. It may be applied . . . . . to improve the physical condition of the land, ... to eradicate blight, or it may even be put on to correct the acidity of soils, although acidity is unknown in India except in peat bheels." At this time methods of determination of the acidity of soils were not highly developed. We know, now, that tea soils with rare exceptions are acid, and many of the best relatively highly acid. Still, although Mann's facts with regard to the acidity of Assam soils were inaccurate, his advice (probably founded on observation in the field), was as usual very sound, and it is the object of this note to produce evidence in support of his opinion that tea soils in general do not need lime.

The evidence comes under two heads—

Laboratory work.

Field Experiments.

The laboratory work includes a large number of determinations of acidity of soils from many districts.

The actual lime content of the soil appears to be of small importance. Soils of high lime content are found to do well under tea so long as they are sufficiently acid. Mann for example quotes a good soil from Jafflong containing 0.77 per cent. lime while many good tea soils in the Dooars approach 0.5 per

cent. in total lime. These soils, however, contain sufficient acid clay to make the soil reaction definitely acid. The lime soluble in citric acid is a better indication of the actual basic lime present, and this figure for " available lime " rarely exceeds .05 per cent. in a good tea soil even when the total lime is high. When, however, the total lime is much higher than about 0.3 per cent. the " available lime " is often in the neighbourhood of .1 per cent., and in such cases the soil may be found to be not acid enough for vigorous tea, or may be even alkaline in which case it has always been found impossible to establish tea. Knowledge of the lime content of the soil is therefore only of value as an indication of the probable acidity of the soil, and hence we get more information from direct measurements of acidity than from measurements of lime content, though the latter are valuable as corroborative evidence. Many methods have been proposed for estimating the acidity of soils, and much time has been spent in trying various methods and modifying them if necessary to see which best serves our purpose, and in this direction much remains to be done.

These facts, however, are already clear, that in general.—

(1) The most acid soils grow the best crops of tea.

(2) Soils of low acidity grow poorer tea.

(3) On soils which are not acid but are neutral or alkaline the attempt to establish tea has always failed.

It will be understood of course that soil acidity is not by a long way the only factor determining the fertility of a soil for tea, so that a slightly acid soil may prove more fertile than a more highly acid soil which is not so good in other respects. Nor, probably, is it true that no tea soil requires lime.

Planters frequently connect soil acidity with water-logging but so far as our experience goes there is no connection between the two. A water-logged area is improved by drainage and not necessarily by liming.

Field Trials.

1. *Experiments with heavy dressings of Lime at Tocklai.*

For this experiment eight plots planted with three-year old tea, were treated respectively with crushed limestone at the rate of 50, 100, 150, 200, 300 and 400 maunds per acre of crushed limestone, and 100 and 200 maunds per acre of quicklime, while a ninth plot was left untreated. At the end of 1921 all the more heavily limed plots were giving greatly reduced crops compared to the crop from the unlimed plot. Even the most heavily limed plot, however, was growing tea which looked quite fair.

This tea was then uprooted and one-year old plants put in on the same plots without further treatment. Differences in growth very soon began to be apparent. Two years after planting the following remarks applied.

Plot 1.	No lime ...	good tea.
,, 2.	50 mds. lime ...	good tea but poorer than 1.
,, 3.	100 mds. lime ...	poor tea, noticeably worse than 2.
,, 4.	150 mds. lime ...	distinctly poor tea.
,, 5.	200 mds. lime ...	still poorer.
,, 6.	300 mds. lime ...	very bad.
,, 7.	400 mds. lime ...	very bad indeed, very little growth since tea was planted.

The plots receiving quicklime behaved similarly but were each a little better than the plot receiving the same quantity of lime as crushed limestone.

When young tea was planted on land limed five years previously, then, the bad effect on tea of excessive lime in the soil becomes very noticeable; whereas there had been no effect very striking to the eye, on the tea previously planted on these same plots.

From other trials it appears that this is not only because newly planted tea is more susceptible, but also that it takes some time for the effect of excessive lime in the soil to exert its maximum effect on tea.

LIMING EXPERIMENTS AT TOCKLAI.

PLOT NO. 1.
No Lime.

PLOT NO. 2.
50 maunds limestone and later the right hand half received an equivalent quantity of sulphur.

PLOT NO. 7.
400 maunds limestone and later the right hand half received an equivalent quantity of sulphur.

2. The use of Sulphur on soils of insufficient Acidity.

If soils of excessive lime content are bad simply because insufficiently acid, then it should be possible to improve them by using an acid substance to neutralise the alkaline lime. For this purpose there are not many substances which are cheap and convenient in application. Powdered sulphur appeared likely to answer the purpose best. Sulphur is known to be slowly oxidised in the soil to give sulphuric acid. An application of sulphur therefore slowly increases the acidity of an acid soil, or reduces the alkalinity of an alkaline soil.

In the Spring of 1924, each of the plots referred to in experiment (1), was therefore divided into two halves, and to one of the halves sufficient powdered sulphur was added to produce sulphuric acid enough to neutralize the lime originally added.

By the end of 1924, the improvement on the tea which had been thus sulphured was striking. Bushes which were already nearly dead, did not suddenly become first class tea; but plants which had received only lime to slow down growth, had made improvement within a year after application of sulphur.

The photographs illustrate these experiments. The first shows Plot No. 1 which received no lime. The second shows Plot No. 2 which received 50 maunds lime and later, in 1924, an equivalent quantity of sulphur was applied to the right hand half of the plot. The improved condition of the sulphured half is easily seen. The third and fourth photographs show the plot which received 400 maunds lime and later an equivalent quantity of sulphur was added to the right hand half of this section.

To one of the plots an extra quantity of sulphur was added by mistake so that instead of changing the soil from alkalinity to an acidity of about 450 (Hopkins method) which is the normal for a soil of the Tocklai type, an acidity of over 7,000 was obtained. This figure is about double that shown by the heaviest clays of North East India yet the bushes are improving.

Indeed it appears that the range of acidity which the tea bush will tolerate is fairly wide both when measured by the

Hokpins method or when the actual acidity (hydrogen-ion concentration) is considered.

Good tea is found on soils with pH varying between about 4.5 and 6.0 yet at Rothamstead it has been shown that a variation of hydrogen-ion concentration from 4.4 to 4.8 is sufficient to distinguish between bad and good wheat.

3. Trials of smaller quantities of lime at Borbhetta.

A block of tea was selected which had been planted with 15 months plants in 1919, and had received no manurial treatment either before planting or during 1919, 1920 or 1921.

In 1921 the block was divided into 64 plots of about $\frac{1}{20}$th acre each and five plots evenly distributed about the block were used for each treatment.

The treatment under trial is a rotation of manuring covering four years.—

First year—lime (1922).
Second year—phosphate and Cowpeas (1923).
Third year—complete artificial mixture (1924).
Fourth year—rahar (1925).

The treatment is the same for all plots during the second, third and fourth years; but the quantity of lime applied in the first year varies in each series. By " series " is meant a set of five plots receiving the same treatment.

The doses of lime applied in 1922 included—

Slaked lime.	*Crushed limestone.*
6¼ mds. per acre	7½ mds. per acre
12½ ,, ,, ,,	15 ,, ,, ,,
do. ,, ,, ,,	do. ,, ,, ,,
25 ,, ,, ,,	30 ,, ,, ,,
	80 ,, ,, ,,

The slaked lime applied was such that 6¼ maunds supplied the same quantity of basic lime as 7½ maunds crushed limestone. Twelve and a half maunds and 25 maunds slaked lime are

similarly equivalent in acidity reducing power to 15 and 30 maunds crushed limestone respectively.

Taking the yield of the plots receiving no lime as 100, the following relative yields were obtained :—

	1921 before liming.	1922 lime applied in March.	1923 bone meal and cowpeas.	1924 complete manure.
No lime	100	100	100	100
6½ mds. slaked lime	105	108	105	100
7½ mds. slaked lime	106	98	96	98
12½ mds. slaked lime	103	108	97	94
12½ mds. slaked lime	107	105	102	103
15 mds. crushed limestone ...	109	105	101	102
15 mds. crushed limestone ...	105	108	105	100
25 mds. slaked lime	110	114	101	100
30 mds. crushed limestone ...	113	108	93	93
80 mds. crushed limestone ...	103	115	104	97

The figures for 1921 were obtained from plucking records for two months only in a year when the young tea gave only 5½ maunds of tea per acre for the whole year. These figures are therefore not reliable. The 1922 figures were from pluckings from the whole season, and the tea in that year yielded 7 maunds per acre. It will be noticed that there is still a loss in yield in every case where lime was applied if the yield in 1924 be compared with that in 1922.

The losses however are in general small only. With regard to small dressings of lime it may be said that they do little harm. This is quite clear since even the plots which received 80 maunds of crushed limestone per acre averaged 12½ maunds pucca tea per acre in 1924. The point is that these small dressings give no increase in crop, and the expenditure on liming shows no return.

Another experiment was tried using no other manures except lime with the following relative results :—Results are again averages from five plots for each treatment.

	1922.	1923.	1924.
15 maunds crushed limestone per acre ...	100	94	93
No lime	100	100	100

Again there is a decrease from the use of lime.

Further experiments were tried using small annual dressings of lime, both alone and in conjunction with mineral manures.

The quantities used were approximately—

Crushed limestone	...	...	224 lbs.	per annum.	per acre.
Sulphate of potash	...	...	396 „	„ „	„ „
Superphosphate	...	...	473 „	„ „	„ „
Sulphate of lime	...	...	272 „	„ „	„ „

The actual quantities were applied after analysis so that they were exactly chemically equivalent. The sulphate of lime is a neutral salt which supplies lime with only very slight change in the acidity of the soil.

Results are again averages from five plots receiving the same treatment.

	1921 before manuring.	1922.	1923.	1924.
No manure	100	100	100	100
Limestone only	113	112	112	104
Potash only	91	95	100	101
Potash and limestone	118	107	111	101
Super. only	113	111	113	99
Super. and limestone	111	108	108	96
Super. and potash	95	96	108	95
Super., potash and limestone	104	101	105	95
Sulphate of lime	108	106	103	97

The differences are small, and irregular, but it is clear that in every case where limestone is used the crop is reduced. The use of the neutral sulphate of lime also reduces the crop.

The results from all these experiments are irregular, and not as concordant as could be desired. Variation due to differences in fertility of the different plots before treatment are not eliminated even by averaging from five plots for each treatment. Still in every case where lime is used the crop is definitely reduced and the number of cases where this occurs is too large to be put down to coincidence.

In our opinion it is already clear that the use of lime on Borbhetta and Tocklai soils gives no increase of crop, but a definite loss of crop, which is at present small.

This is the more remarkable since the soil is relatively highly acid, and liming would undoubtedly prove beneficial for most crops. On the very plots on which lime caused a depression of the tea crop, the cowpeas grown in 1923 showed a decided preference for the limed plots in that the more heavy the dose of lime the heavier was the crop of cowpeas grown. The cowpeas crop from the most heavily limed plots averaged just about double that from the unlimed plots. On adjoining land we had previously found that both guinea grass and maize were benefited by lime, while jowar could not be made to grow at all without the use of lime (see Q. J. 1919). On the Government Experimental Farm just over our fence all crops tried including sugar, cowpeas, mustard and rahar benefit markedly from lime, while oats would not grow at all without it. It is clear then that different plants show different requirements for lime on the same soil, and that here is one case at any rate when tea requires no lime on a soil where most plants do require fair quantities of lime.

Experiments on Gardens.

In addition to the experiments described there are about 60 other experiments on the use of lime on different tea estates mainly in the Dooars. These have been in progress for three years only, in which case initial differences in the fertility of the soil before it was under experiment make exact comparisons extremely difficult.

The results therefore are not yet worth quoting in full. Records however are being carefully kept and in no case has a limed plot shown an increase over an unlimed plot sufficiently great to be considered significant, while in the great majority of cases, the evidence pointing to a small depression in crop from the use of lime is fairly clear.

There is a certain amount of evidence that soil acidity may be associated with increased liability to attack by mosquito blight,

and on two classes of soil the use of lime appears to give very slightly increased crop when mosquito blight is present. These are the heavy acid red clays of the Dooars Red Bank and the dark acid sands ("Mal sands") of the Western Dooars. On other soils this increase has not been observed, while it is still doubtful whether the apparent increase on these two classes of soil is really significant.

Other cases where lime appears at first to give increased crop are where lime is used in conjunction with either an organic manure (like oilcake or animal meal) or with sulphate of ammonia. In such cases the use of lime often gives a small increase in the year of application. The increases so obtained, however, and are not equal to the increase obtainable by the same expenditure on additional nitrogen. It appears probable that the increase obtained is due to the increased immediate availability of the nitrogenous manures, and is not due to the lowered acidity of the soil. These cases also will be watched and further investigated.

The chief exceptions to these observations come from gardens in the Doom Dooma district where carefully conducted experiments show that liming has an undoubtedly beneficial effect on certain soils. Here a dose of 80 maunds lime per acre generally depresses the crop or gives a small increase but smaller doses of 60, 40 or 20 maunds, give increases varying from 10 to 16 per cent. above the non-limed plots. An application of 10 maunds gives an increase of about 3 per cent.

Conclusions.

Our opinion, on the evidence available may be briefly expressed thus:

Tea only grows well in soils which are definitely acid, and a relatively high degree of acidity appears to favour rapid growth. A high degree of acidity appears to act as a stimulant to tea, but stimulants in excess may prove harmful and such an excess is reached when very heavy top-dressings of acid peat-bheel are applied to sandy soils very low in lime as are Surma

Valley teelas. In such cases the first effect has always been an enormous increase in crop, which is followed in later years by serious deterioration of the tea due to attack by disease. In such cases lime has often proved useful ; and although we have no definite experiments in support of the supposition, it is probable that lime would in some cases prove useful on very acid peat-bheel soils which are suffering from diseases.

Certain root diseases also are encouraged by excessive soil acidity, and will not grow in alkaline soil ; these diseases may be usefully treated with lime.

On excessively heavy soils an application of lime will render the soil more permeable to water and to plant roots : in such cases lime may often prove valuable if used in quantities which still leave the soil definitely acid.

With the exception of such cases, lime on tea soils in small quantities is likely to have generally no good effect, while in quantities large enough to reduce the soil acidity greatly, it will cause definite loss of crop.

THE FIELD EXPERIMENTS AT TOCKLAI.

BY

E. A. Andrews.

No. 1. THE PLUCKING EXPERIMENT.

Visitors to the Experimental Station at Tocklai are made aware of the fact that on the land available several series of experiments are being conducted which, while necessarily much less extensive than those at Borbhetta owing to the restricted area available, are yet not devoid of interest. Little has so far been published regarding these experiments, for experience has shown the considerable variation normally existing between plots of apparently similar tea in the field, and forced home the realisation that the results of small scale experiments must be examined with a considerable degree of caution. In the case of certain of these experiments, however, a stage appears to have been reached at which a discussion of the indications afforded to date may be not unprofitable, and it has been decided to commence the publication of the information which is accumulating in order that members of the Association may be kept acquainted with the progress of the experiments.

This article deals with certain trials which are being carried out with regard to the effect of different systems of plucking.

The tea on which the trials are being made is a small area of about $\frac{2}{5}$ ths of an acre, which was planted in the cold weather 1915-16 with Burma and Manipuri plants remaining from the nurseries used for planting out the area, given over to jat trials, which has come to be known as "The Clearance." The plot is on slightly sloping ground, and was originally designed for the exhibition of the various methods of dealing with sloping ground by contour draining, bunding, terracing, etc.

The experiment is laid out in three sets of nine lines of bushes, the lines running down the slope, in an East and West direction. In each set nine styles of plucking are repeated, and the leaf weighed separately.

No preliminary records were kept of the outturn of the various lines to ascertain the intrinsic differences between them before commencing the experiment, and in looking for results reliance has to be placed on the cumulative effect of repetition of the various treatments year after year. It is in consequence of this that publication has been delayed until it became probable that the results being obtained were due to the effect of the various treatments, and not to intrinsic differences between the various lines, which, especially since no particular order was observed in planting the Burma and Manipuri bushes, must have been considerable.

The styles of plucking adopted fall, to begin with, into three classes, according to the degree of hardness of the plucking.

In the first class the bushes are first plucked to leave six inches of new wood, and afterwards to the jhannum.

In the second class they are first plucked similarly, at six inches, but in subsequent pluckings a leaf and a jhannum is left throughout the season.

In the third class the bushes are originally plucked at four inches, and in subsequent pluckings a leaf and a jhannum is left throughout the season.

The bushes are plucked every seven days, the leaf which is taken being two leaves and a bud.

The lines which fall into each of the three classes detailed above are, in addition, plucked differently according to three systems.

In the first system all " bhanjy " shoots are plucked, the bhanjy bud and the first leaf being taken, and weighed if the leaf is soft, thrown away if the leaf is hard. At the same time, all shoots are " broken back " where necessary ; that is to say,

should there be three leaves and a bud, or more, above the plucking point, the two leaves and a bud are plucked and weighed, while the extra leaf, or more, above the plucking point, is broken off and thrown away.

In the second system bhanjy shoots are plucked in the same way, but no breaking back is done, any excess over the two leaves and a bud being left on the bush.

In the third system all shoots are broken back where necessary, but all bhanjhies are left on the bush.

The following table will make the classes and systems clear :—

TABLE I.

Plucking systems tried in the experiment.

1	Plucked to 6 inches, then to the jhannum	Broken back ...	Bhanjhies plucked.
2	Do. do. ...	Not broken back ...	Do.
3	Do. do. ...	Broken back ...	Bhanjhies left.
4	Plucked to 6 inches, then to a leaf	Broken back ...	Bhanjhies plucked.
5	Do. do. ...	Not broken back ...	Do.
6	Do. do. ...	Broken back ...	Bhanjhies left.
7	Plucked to 4 inches, then to a leaf	Broken back ...	Bhanjhies plucked.
8	Do. do. ...	Not broken back ...	Do.
9	Do. do. ...	Broken back ...	Bhanjhies left.

In succeeding tables, for the sake of brevity and clarity, the following abbreviations and signs are used :—

Plucked to 6 inches, then to the jhannum ...	6
Plucked to 6 inches, then to a leaf ...	6 L.
Plucked to 4 inches, then to a leaf ...	4 L.
Broken back	B.B. +
Not broken back	B.B. –
Bhanjhies taken	B.J. +
Bhanjhies left	B.J. –

The plants, which had been collar-pruned and then left unpruned, were cut at about 18 inches in the cold weather 1920-21, and plucked according to the different systems, for the first time, in 1921. In all, there are 29 lines. Lines 1 and 29, being alongside the drains at the edge of the plot, were not included, so that lines 2 to 10 form the first series, lines 11 to 19 the second series, and lines 20 to 28 the third series, each series being a repetition of the others.

Table II gives the yield, in maunds of made tea per acre, of the various lines for the years 1921, 1922, 1923 and 1924.

It will be observed that in 1921 the yields of the three series were not recorded separately.

The method adopted for calculating these yields is as follows.—

The actual leaf is weighed, and the outturn of leaf per bush calculated by dividing the outturn for the line by the number of bushes in the line. In this way the yield of leaf in ounces per bush is obtained. This is then multiplied by 1,742, which is the number of bushes per acre when they are planted, as in the case of the tea under discussion, 5 feet apart, in squares. In this way the yield of leaf in maunds per acre is obtained. It has then been assumed that 4 maunds of leaf give 1 maund of dried tea, and ¼ of the yield of leaf per acre has been taken as the yield of made tea per acre. In counting the number of bushes per

line, infills which are not yielding fully have been counted as half bushes :—

TABLE II.

Yield in Maunds of Made Tea per acre.

Treatment.	Line.	1921.		1922.		1923.		1924.	
		Yield.	Average Yield.	Yield.	Average Yield.	Yield.	Average Yield.	Yield.	Average Yield.
BB. BJ.									
6 + +	10	—	10·6	12·5	12·8	13·8	13·7	10·3	10·2
	19	—		12·1		12·1		10·1	
	28	—		13·8		15·2		10·1	
6 − +	3	—	10·6	13·2	13·5	12·5	12·8	10·2	9·9
	12	—		14·3		12·9		9·0	
	21	—		12·9		13·0		10·5	
6 + −	2	—	8·2	10·5	10·4	11·8	11·3	9·5	9·5
	11	—		11·5		11·8		9·4	
	20	—		9·2		10·2		9·7	
6L + +	6	—	8·5	9·4	9·2	10·1	9·9	8·5	8·1
	15	—		9·7		10·0		7·6	
	24	—		8·5		9·7		8·2	
6L − +	4	—	7·6	8·7	8·4	8·9	9·6	10·6	10·0
	13	—		8·3		11·1		10·7	
	22	—		8·3		8·8		8·7	
6L + −	5	—	5·9	8·3	7·9	7·6	8·0	7·0	7·2
	14	—		7·9		8·2		7·5	
	23	—		7·6		8·1		7·0	
4L + +	9	—	7·9	12·9	12·8	12·9	11·6	9·1	8·5
	18	—		10·5		10·0		8·7	
	27	—		15·0		12·0		7·7	
4L − +	7	—	7·9	9·8	9·9	9·7	9·8	9·2	8·4
	16	—		8·9		9·5		7·8	
	25	—		10·9		10·2		8·1	
4L + −	8	—	6·0	9·5	9·4	8·4	9·2	7·3	7·6
	17	—		8·9		9·8		7·9	
	26	—		9·8		9·4		7·7	

The Effect of the Class of Plucking.

We will first consider the different classes of plucking. There are three sets of lines plucked at 6 inches, and then to the jhannum ; three sets plucked at 6 inches, and then to a leaf ; and three sets plucked at 4 inches, and then to a leaf. By adding together the average yields of each set for the four years, and dividing by three, we obtain the average yield per

acre, to date, of the bushes plucked in the three different ways. This is shown in the following table :—

TABLE III.

The Effect of the Different Classes of Plucking on the Yield.

Class of Plucking.	Yield to date (1921 to 1924 inclusive) in Maunds of Made Tea per acre.
6	44·5
4 L	36·3
6 L	33·4

This table shows very distinct differences between the three classes, differences which still obtain when similar figures are extracted from Table II, for each series of lines separately, for three years 1922 to 1924 inclusive. These figures are shown in Table IV.

TABLE IV.

The Effect of the Different Classes of Plucking on the Yield, as shown by each separate series.

Class of Plucking.	Yield to date (1922 to 1924 inclusive) in Maunds of Made Tea per Acre.		
	First Series. (Lines 2 to 10.)	Second Series. (Lines 11 to 19.)	Third Series. (Lines 20 to 28.)
6	34·8	34·4	34·9
4 L	30·3	27·3	30·3
6 L	26·4	27·0	25·0

The differences shown in the above two tables are of course due to two causes :—first, the intrinsic differences in the lines of bushes themselves ; second, the differences brought about by the different methods of treatment.

The intrinsic differences between the lines, as has been stated above, are not known. The enormous variation, between class 6 and 6L, of approximately 3 maunds per acre of tea

per season, is not beyond the limit of variation which we know to exist between different plots of tea in the field. But, it is hardly conceivable that in each set of lines we have happened to strike the three best to be plucked at 6 inches, and then to the jhannum ; the three worst to be plucked at 6 inches, and then to a leaf ; and the three intermediate lines to be plucked at 4 inches, and then to a leaf. Moreover, in Table IV it may be seen that the largest variation in yield in the case of any one class of pruning, a variation undoubtedly due to intrinsic differences between the lines of bushes, amounts only to 1 maund per acre per year. It would therefore appear to be more than probable that the order of yield, which the lines plucked in the different ways have assumed, has been brought about by the different classes of plucking, and should this order be maintained in subsequent years the evidence will be incontrovertible.

At the end of 1924, for the first time, measurements were made to ascertain the effect of the various classes and systems of plucking on the thickness of the pruning wood. The observations made in this connection can only be regarded as of a preliminary nature, but are worthy of record for comparison with the results to be obtained in subsequent years. The best method of making these observations is of course to collect and measure the prunings taken from the bushes. In subsequent years this is to be done. The decision to make these measurements was, however, made too late, this year, for this to be done, and the measurements given, which will also be repeated, for comparison, in subsequent years, were made as follows :—One bush was marked down, in each line of each series, after pruning, the bushes selected being even in character, as regards general growth and development. Each centre branch, and each side branch, was traced to its terminal shoot, the diameter of which was measured with a micrometer at a point midway between the first and second bud from the previous pruning. The measurement of every shoot was tried, but was found to be impracticable. These measurements, however, made, for the same bushes, year by year, along with measurements of the actual prunings made under more

favourable conditions in the laboratory, should afford reliable indications of the effect of the various treatments on the thickness of the pruning wood in general, and on the development of the wood on these bushes in particular.

The results of the observations made in this connection are given in Table V, the figure given being the average diameter of the terminal shoots, midway between the first and second bud, in decimals of an inch.

Table V.

Thickness of Wood.

Treatment.			Line.	Centre Shoots.	Average.	Side Shoots.	Average.	Mean of Centre and Sides.	Average.
	BB.	BJ.							
6	+	+	10	·235	·248	·212	·203	·223	·225
			19	·248		·214		·231	
			28	·260		·183		·221	
6	−	+	3	·252	·252	·173	·192	·212	·222
			12	·219		·186		·202	
			21	·284		·218		·251	
6	+	−	2	·233	·268	·197	·214	·215	·241
			11	·281		·225		·253	
			20	·291		·220		·255	
6L'	+	+	6	·228	·256	·229	·210	·228	·232
			15	·247		·178		·212	
			24	·294		·222		·257	
6L	−	+	4	·244	·290	·173	·209	·208	·249
			13	·275		·190		·232	
			22	·350		·265		·307	
6L	+	−	5	·300	·281	·211	·210	·255	·245
			14	·225		·185		·205	
			23	·317		·235		·276	
4L	+	+	9	·252	·266	·208	·191	·230	·228
			18	·252		·171		·211	
			27	·294		·194		·244	
4L	−	+	7	·257	·274	·216	·208	·236	·241
			16	·273		·217		·245	
			25	·291		·191		·241	
4L	+	−	8	·302	·273	·189	·187	·245	·230
			17	·226		·180		·203	
			26	·291		·191		·241	

In Table VI the figures for the different classes of plucking are extracted, and given alongside the yields to date.

TABLE VI.

The Effect of the Different Classes of Plucking on the Thickness of the Pruning Wood.

Style of Plucking.	Yield to date in Maunds of Made Tea per acre. (1921 to 1924 inclusive.)	Diameter of pruning wood at end of 1924.		
		Mean (inch).	Centre (inch).	Sides (inch).
6	44·5	·229	·256	·203
4 L	36·3	·233	·271	·195
6 L	33·4	·242	·276	·210

From this table it will be seen that the mean thickness of the pruning wood obtained, so far as is indicated at present, varies in an inverse manner to the yield, thinner wood accompanying a higher yield, and that this effect, as would be anticipated, is more marked in the centre, where the bush is more productive, than at the sides. This observation can as yet only be regarded as tentative, but it will be seen later, in discussing the effect of breaking back and of plucking bhanjhies, that more than mere coincidence would seem to be demanded to explain this phenomenon.

To sum up, it would appear to be indicated that plucking to 6 inches, and then to the jhannum, has proved more profitable than either of the methods in which, by leaving a leaf, the bush has been allowed to make growth throughout the year. Moreover, the loss in leaf has increased with the amount of growth left on the bushes, the ones originally plucked at 4 inches and then to a leaf having yielded better than those originally plucked at 6 inches and then to a leaf. The lighter plucking has been productive of an increased thickness of wood, particularly in the centre of the bush.

The Effect of "Breaking Back."

In Table II it will be seen that each class of plucking has been combined with the principles of breaking back, not breaking back, plucking bhanjhies, and leaving bhanjhies, in various combinations, and that it is possible to deduce the effect of these differences from the results of the lines so treated that the only difference between them is that of breaking back or not doing so, or of taking or leaving bhanjhies.

Thus, taking the class plucked at 6 inches and then to the jhannum, we find that lines 10, 19, and 28 were broken back, while lines 3, 12, and 21 were not, but that in other respects they received the same treatment. Similarly with lines 6, 15, and 24, as compared with lines 4, 13, and 22 ; and with lines 9, 18, and 27, as compared with lines 7, 16, and 25.

On calculating the average total yield to date, in maunds of made tea per acre, of those various sets of lines, we obtain the yields given in Table VII.

Table VII.

The Effect of Breaking Back.

Treatment.	Yield to date in Maunds of Made Tea per acre. (1921 to 1924 inclusive.)	Diameter of pruning wood at end of 1924.		
		Mean. (inch).	Centre. (inch).	Sides. (inch).
Broken back (B. B.+) ...	41·3	·228	·257	·201
Not broken back (B. B.−) ...	39·5	·237	·272	·203

In this table the thickness of the wood of the bushes concerned, measured as recorded in the discussion of the effect of the different classes of pruning, is also inserted.

These results indicate an increased yield produced by breaking back, with thinner wood accompanying the increased yield, as in the former case. The difference in yield, however, is not nearly so pronounced as in the former case, and, in fact,

when considering the three series of lines separately, it is found that in two cases out of the three the bushes which were not broken back have shown a slightly increased yield, due in great part to the behaviour, in 1924, of the bushes originally plucked to 6 inches, not broken back, and with bhanjhies plucked (6L, B.B. –, B.J. +), which after being amongst the three lowest yielding plots until 1923, unaccountably jumped from seventh to second place in 1924. The average yield per acre to date of the separate series is shown in Table VIII.

TABLE VIII.

The Effect of Breaking Back.

	Yield to date in Maunds of Made Tea per acre (1922 to 1924 inclusive).		
	First Series. (Lines 2 to 10.)	Second Series. (Lines 11 to 19.)	Third Series. (Lines 20 to 28.)
Broken back (B.B. +) ...	33·2	30·3	33·4
Not broken back (B.B.–) ...	34·3	30·8	30·5

The Effect of Plucking Bhanjhies.

On extracting from Table II the figures for the lines showing taking and leaving bhanjhies as the only difference, in the same way as was done in considering the effect of breaking back, we obtain the differences in yield shown in Table IX.

Table IX.

The Effect of Plucking Bhanjhies.

	Yield to date in Maunds of Made Tea per acre. (1921 to 1924 inclusive.)	Diameter of pruning wood at end of 1924.		
		Mean. (inch).	Centre. (inch.)	Sides. (inch).
Bhanjhies plucked (B. J. +)	41·3	·228	·257	·201
Bhanjhies left (B. J.—) ...	33·5	·239	·274	·204

Here we observe that the effect of taking bhanjhies has been a considerable increase in yield. There is also, again, a decrease in the thickness of the wood accompanying the increase in crop, and the effect of leaving bhanjhies has apparently been to thicken the wood both at the centre and the sides. In this case the three series of lines show results in entire accordance, in each case, with those obtained on the average, as is shown by Table X.

Table X.

The Effect of Plucking Bhanjhies.

	Yield to date in Maunds of Made Tea per acre (1922 to 1924 inclusive).		
	First Series. (Lines 2 to 10.)	Second Series. (Lines 11 to 19.)	Third Series. (Lines 20 to 28.)
Bhanjhies plucked (B J. +) ...	33·2	30·3	33·4
Bhanjhies left (B. J.—) ..	26·6	27·6	26·2

Summary.

While these plucking experiments have obviously not been continued, as yet, for a sufficient period to permit of irrefutable statements being made regarding the effect of the different treatments under trial, it is apparent that they have now reached a stage at which their future progress will be watched with interest by members of the Association.

The main indications afforded to date appear to be—

(1) Allowing the bushes to continue to make growth after plucking has commenced has resulted in a decrease of crop.

(2) This has occurred whether this continued growth has been the result of the class of plucking adopted, of not breaking back the overgrown shoots, or of leaving bhanjy shoots on the bush, although as regards yield the effect of not breaking back has so far been irregular.

(3) In all cases thicker pruning wood has accompanied a lower yield, and *vice versa*, the increase or decrease being greater in the more productive centre of the bush than at the less productive sides.

(4) There is no evidence of the wood in the centre of the bush being thickened at the expense of the sides in any of the cases, but rather the reverse.

Should these indications continue, during successive seasons, until they become certainties, the results will probably occasion little surprise among experienced planters. They will, however, emphasize the enormous amount of leaf which can be lost by certain methods of plucking ; they will, moreover, point to the fact that if both better wood and increased crop be desired at the same time, operations other than that of plucking must be looked to to bring this about. In the meantime, the present position of the experiment is placed on record for comparison with the results of succeeding years.

METEOROLOGICAL OBSERVATIONS IN ASSAM, 1924,

BY

C. R. HARLER.

CORRELATION AND CAUSATION.

Although the climate of North East India is extremely variable over about six months of the year, the monsoon hardly ever fails. When once the tea bush is established the individuality of any particular season is to a great extent masked owing partly to the recuperative powers of the bush and partly to the fact that there are no critical periods of seed time or blossom time and the harvest is spread over a period of eight or nine months. At present most of the tea is not yielding to capacity but were this so the effect of different seasons on the crop would be much more marked than it is at present.

The tea industry in India is too young to have its own weather lore and to establish a correlation between the tea crop and weather is a task fraught with difficulties. It is however easier to correlate certain phases of the growth of the bush with weather conditions. The effect of severe early drought on tea cut back late or on unpruned tea is unknown and understood. In the Surma Valley a bad drought is associated with acute mosquito attack later in the season although this correlation is probably an indirect one for the reverse holds in the Dooars. In the Surma Valley many of the bushes are so weak to begin with that the extra strain imposed by the drought puts an end to any power of resistance.

In many cases incorrect correlation is deduced owing to a limited number of observations. Thus as the result of one season's experience tea pruned in a certain manner or unpruned tea may be regarded as a failure and the experiment is never tried again. Unpruned tea is generally a gamble with the

weather but a percentage of unpruned tea over a period of years will pay whilst a policy of change may lead to a serious loss or, if the good years happen to be struck, to a great gain.

An interesting case of faulty correlation and an assumption of causation occurred in certain districts in 1923. In that particular year many gardens used a certain spray for mosquito blight and as the attack was lighter than usual the spray was considered to have been responsible. Experience in 1924 changed the former view for the attack following on the early drought was unusually severe in spite of liberal spraying.

When two sets of happenings are correlated we need some outside evidence before we can assume causation. For many years it was considered that green fly in some way brought flavour to the tea leaf. It is now believed that certain weather conditions induce flavour and may be, at the same time, favourable to green fly. If this be so, there is correlation between the two happenings but causation has not yet been proved and is indeed doubtful.

When the ideal conditions for tea growth have been defined it will still be difficult to interpret the crop results. For, of the numerous atmospheric and soil factors affecting the crop in various degrees, any one, which is ordinarily a minor factor, is capable of becoming a limiting or controlling factor. Although atmospheric conditions may be ideal the waterlogging of the soil may decide against a good flush. The soil condition may be perfect but a temperature in the neighbourhood of 100°F may vitiate any calculations of the crop made in the light of other influences.

The most important need at present is that of data from the laboratory and the plant physiologist must first determine which factors affect plant development in order that the meteorologist shall know which observations to make. We know that the jungle surrounding our tea gardens contains all the diseases which attack tea and that the spores of these diseases have every chance of spreading, yet the range of destruction of a blight may vary from zero to thousands of maunds of the crop and, so far as we can

see, conditions have been well within the limits congenial both to the bush and to the parasite. During the present year (1924) a stem disease *(Corticium sp.)* became noticeably prevalent probably because some factor lowered the resistance of the bush but since that factor is unknown to us we can only treat the disease by such direct methods as spraying and pruning.

The Monsoon in Assam, 1924.

Broadly speaking there are two sets of winds blowing steadily across the earth, the trades and the anti-trades. The trade winds blow from the north and south to the Equator but, owing to the revolution of the earth, the general direction is from the north-east and south-west. In the temperate zones the complements of these winds, the anti-trades, are met blowing from a south-westerly direction in the northern and a north-easterly direction in the southern hemisphere. Between these two sets of winds are two belts of calm where are found the deserts and the Sargasso seas.

But for the land mass of Central Asia the peninsula portion of India would be in the course of a steady trade wind from the north-east and northern India would be included in the chain of deserts formed by Sahara, Arabia, Persia and the Thar desert. As it is, the land mass of Asia warms up in the summer months and there follows a general flow of air from the southern latitudes to take the place of the air rising from the Asiatic plateau. Eventually this air flow becomes strong enough to overcome the north-east trade wind and then the south-west monsoon begins to blow. The strength of the monsoon varies with each season and although the ultimate cause of this variation has not been decided it depends in part, at any rate, on the oscillations of the two winds which are pitted against each other.

Near Ceylon the monsoon current splits into two main components, one running up the east coast of Africa and the other round the Bay of Bengal.

The current moving up the African Coast sheds copious rainfall on the Abyssinian plateau which floods the Nile and enables

the Egyptian crops to flourish in a permanently cloudless sky. After meeting the Abyssinian plateau the current makes an eastward turn passing Cape Gardafui and the island of Socotra and having lost practically all its northerly component reaches Bombay from almost due west. The rainfall at Bombay is 150 inches but inland it decreases quickly and Poona has an average of under 30 inches although further from the coast there is an increase again. Arabia, Persia and Sind thus miss the monsoon and Karachi has a rainfall of under 10 inches.

The Bengal current is weaker than the African one. During its movement round the Bay it serves the southern part of Burma and then comes to Bengal. Both currents are influenced by a depression which occurs in part of Sind and Rajputana.

Towards the end of the season the Bengal current is caught up in cyclones which whirl it across India and the rainfall brought in this manner has a great influence on the winter crops.

Before the summer is finished the attraction towards Central Asia begins to weaken, and by the autumn the air flow definitely begins to turn southward and the cloud canopy is withdrawn from northern India. The north-east trade wind, previously extinguished by the monsoon, is now reinforced by cold, dry winds blowing from the desert of Tibet which warm up as they cross the Bay of Bengal and pick up moisture to be deposited later on the southern half of Madras.

From the above brief account of the general air movements over India it will be understood that Assam and the north-east corner are out of the track of the monsoon, yet on account of the general air drift towards the Tibetan plateau there is a steady flow of moist air into this area. Furthermore the Himalayan barrier and the funnel shape of the Surma and Brahmaputra Valleys ensures that clouds, when they once enter the country, are shepherded round the hills till they are deposited as rain. Because of this, Assam is one of the permanently green provinces in a continent where conditions are, on the whole, arid.

In Assam the rainfall varies over a wide range. At Cherrapunji, one of the wettest spots on earth, it averages 381

inches with a maximum record of 905. In Silchar it is 122 inches, in North Lakhimpur it is more than 160 inches and at Dibrugarh 112 inches. In the rain shadows of the Mikir hills in the Golaghat district, it drops to about 50 inches.

At Tocklai the average for the past seven years is 80 inches although there has been a wide variation on either side of this value. From 1917 to 1924 the values recorded have been 97, 75, 68, 82, 74, 101 and 66 inches. No two seasons have been alike except in so far as the monsoon is concerned.

In 1924 the early drought was severe for the third year in succession. There was only a slight fall in March (0.39 inches) which was insufficient to penetrate the soil mulch. The first satisfying fall did not arrive till April 12th when 1.06 inches of rain was recorded, but from this date rain was plentiful and dull cool weather and cloudy skies characterised the remainder of the month.

As a result of the drought, dead wood on the tops of the bushes was common and red spider, red rust and *Thyridaria tarda* (die back), all aggravated by the dry spell, were particularly bad. Black rot and another *Corticium sp.* were also common during the year and may be correlated perhaps with certain climatic conditions.

In 1922 the drought ended on March 27th and in 1923 on April 1st and during the present year (1924) on April 12th as mentioned above. In 1919, a notable year for the early drought, the rain came on April 11th although matters had been made worse by the early close of the previous monsoon.

In the middle of May (1924) the rain failed again and the bushes, recovering from the early drought, received another check. The wind continued to blow from the north, our dry quarter, and it was not until June 19th that rain fell. Before this date clear skies, a dry atmosphere and high temperatures were common. The record maximum for Tocklai of 101°F was recorded on June 6th.

The monsoon with its heavy banks of clouds and generous falls did not arrive till June 27th. The rain continued till

October 16th and, combined with high temperatures and humidity, made conditions ideal and the result was a bumper crop in that month.

In November, rainfall was again plentiful but the drop in humidity and temperature caused the bushes to shut up and the season really ended on the 14th of the month. The good end to the season partly compensated for the poor start but the gardens in Lower Assam were behind on their estimates.

Below is given the monthly rainfall at Tocklai during 1924 and the average during the last 6 years.

Table showing Rainfall at Tocklai.

	Jan.	Feb.	Mar.	Apl.	May	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Average	0·51	1·45	3·51	9·18	9·35	14·43	15·82	14·24	10·64	4·39	0·65	0·04	84 21
1924	0·49	1·92	1·01	6·84	6·10	6·36	17·94	7·52	9·58	5·62	2·92	nil	66·30

Hail.

There is always a danger of hail in the tea districts up to the middle of May. In the Brahmaputra Valley, hail is not so serious as in the Dooars and the Surma Valley where it is an annual visitation. Hail usually comes with a black cloud, a rush of cold wind and peals of thunder and the attack may extend for a considerable distance but over a small front. Hailstones of an inch and even in diameter more are common.

The large hail always occurs with thunder storms and follows on a sharp upward movement of the air which carries the moisture from rain clouds up to a height of 4,000 to 5,000 feet. At this height the moisture at the top of the cloud becomes frozen and forms ice particles and the moisture in the centre of the cloud becomes super-cooled, *i.e.*, cooled below freezing point, yet it is still liquid. Such a state is unstable, and when these super-cooled drops come into contact with the ice particles they suddenly solidify and form hail stones at a temperature of 32°F (the temperature at which water freezes).

The nucleus of a hail stone is thus formed suddenly and air bubbles are mixed with ice to form a cloudy, opaque ball. This hail stone may then descend slowly through the clouds and pick up more water which forms layers of ice at a much slower rate than before with the result that no air is included and a clear layer of ice is put round the opaque nucleus. A section of a hail stone shows successive layers of clear and cloudy ice which denotes the life history of the stone.

Hail stones are usually spherical. The elliptical ones are due to the bursting of round ones.

Several methods have been employed to obviate the damage done by hail storms, but since all were based on the assumption that hail is produced by electrical phenomena, they have failed.

The damage to tea done by hail, apart from the wounds to the older wood, amounts to a pruning of the green shoots or to a very hard plucking. If the red wood is cut it is necessary to prune the wood to an eye. In either case it is often advisable to manure with quick acting nitrogen and potash or nitrogen and phosphoric acid according to the nature of the soil.

Sunshine.

Below is given a table showing the average daily sunshine in hours, recorded at Tocklai during 1924 together with the monthly average for the past six years. It will be noticed that the early part of the year is, owing to the drought, characterised by sunshine above the average. During the second half of the year sunshine was in serious default.

Table showing Sunshine at Tocklai.

	Jan.	Feb.	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Average	5·6	5·7	5·6	5·1	4·7	4·0	4·0	4·4	4·1	6·0	5·8	5·4
1924	4·3	6·4	7·0	4·6	5·1	4·0	3·4	3·8	3·7	5·1	3·2	3·5

The measurement of sunshine is wholly neglected in the planting districts although many planters suspect a correlation between it and the severity of mosquito blight.

That the tea bush thrives under shade is obvious on practically all gardens but it is also possible and even common for shade to be too dense.

Experiments were carried out on two gardens in Darrang to find the effect of shade on crop and quality. The tests were made on three blocks in each case with the following results :— The table shows the width of planting of the shade trees and the crop obtained.

Bishnath shading.	Yield (Green leaf).	Tezpur shading.	Yield (Green leaf).
30′ × 30′	224 mds.	60′ × 30′	244 mds.
30′ × 60′	245 ,,	60′ × 60′	260 ,,
nil	233 ,,	*nil*	259 ,,

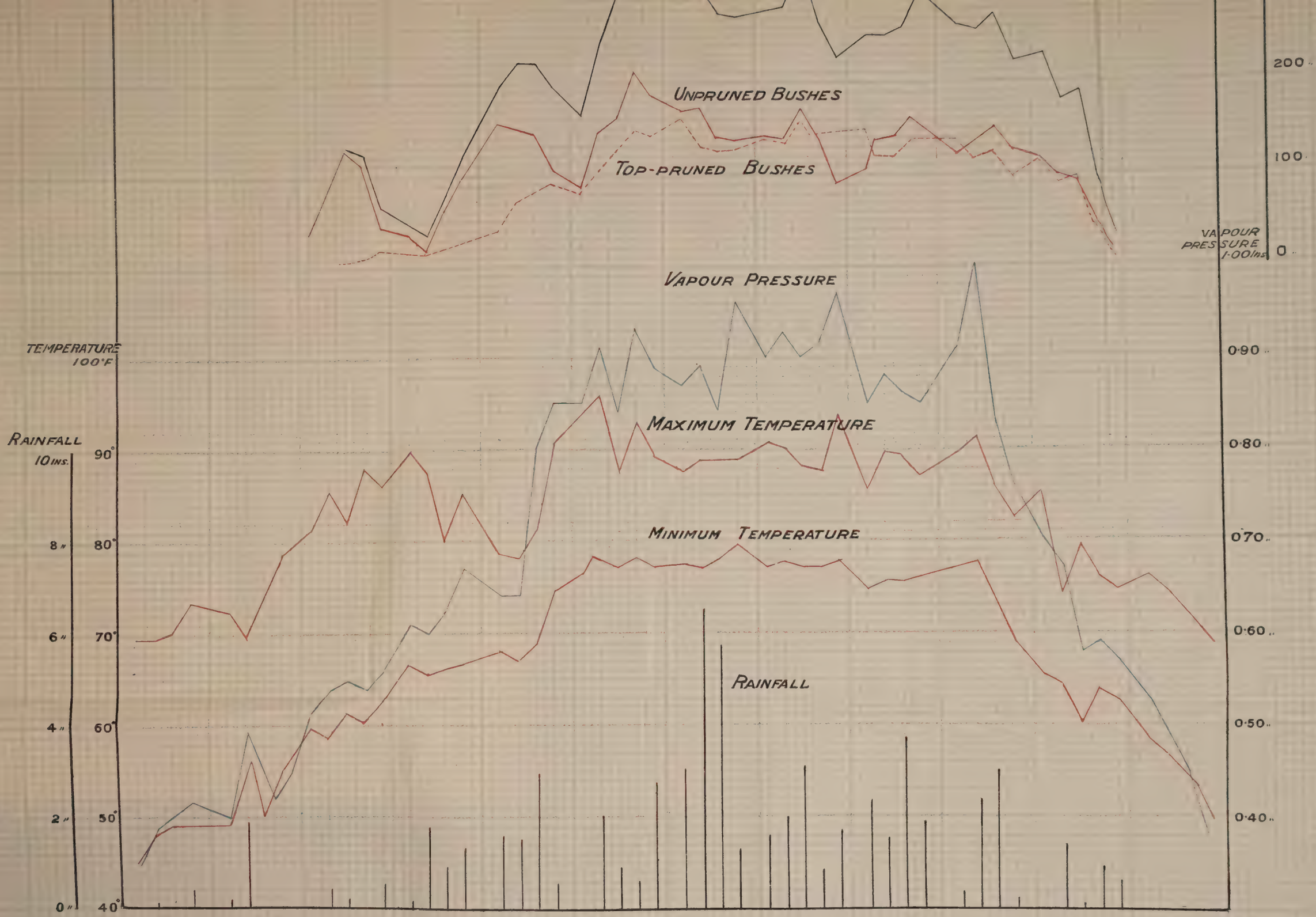
Although the yields are not directly comparable an indication as to the best width of planting shade trees is given. The trees in question were eight years old Sau (*Albizzia stipulata*) which has been lopped.

The teas from the experiment on the Bishnath garden were manufactured separately and tasted each month in Calcutta. In May, July, August and October the teas from the lightly shaded sections were definitely the best. In September when all the teas were similar, preference was given to the lightly shaded section. In May, July, August, September and October the teas from the unshaded section were the second best. In June they were the best and in November the worst. The heavily shaded section gave the worst teas in every month except November, when it gave the best, and June, when these teas were about equal to the others.

The Weather Chart for 1924.

Of the climatic factors influencing the tea crop the two most important are the moisture content of the soil and the atmospheric humidity.

On the chart for 1924 the soil moisture is shown on the top black curve and the atmospheric humidity or vapour tension,



OBSERVATIONS MADE AT TOCKLAI EXPERIMENTAL STATION

in inches of mercury, is shown by the blue curve. The humidity is the complement of both rainfall and temperature. Our rain bearing breezes blow from the south-west and arrive moisture laden, but at the same time the amount of moisture which remains in the air depends on the temperature, and the close correlation between temperature and vapour pressure is shown on the chart. The weeks ending July 13th and 20th are exceptions for here the rainfall is at its heaviest yet the vapour tension is depressed. What actually happened was that the average temperature over this period was so low that atmospheric saturation at that temperature represented a much lower figure than partial saturation at a higher one.

Keeping in mind the fact that any other factor in plant growth—wind, temperature, radiation, plant food in the soil, soil condition, etc., may well become the limiting factor, it is of interest to attempt to correlate crop with humidity and soil moisture. The total crop curve from the Tocklai Clearance is taken for this purpose. The black crop line denotes the total crop from an area of 2½ acres half of which was unpruned and half top pruned at 20 inches in 1924. The two red lines denote the crop from the two styles of pruned bushes and these two crops make up the total.

In an ideal season with no exceptional weather conditions we should expect an increasing crop till about July and then a steady yield till September and a decrease till November somewhat sharper than the early increase. Along this general curve there would be periods of secondary increases corresponding with the monthly flush.

In 1924 the bushes came away with the Spring growth in March but were practically shut up in April on account of the dry condition of the soil. With rain came the May flush, a week or two late, followed by a depression which may be taken as the aftermath of the early drought. The June or second flush was a good one but would have been better but for the dryness of the soil early in the month. Towards the end of June, brown blight attacked the flush and most of the young shoots died back

necessitating a light top prune. On this account the July flush was missing.

Taking 15 per cent. as approximately the optimum for Tocklai soil it will be seen that the soil moisture was fairly satisfactory from the end of June onwards.

The August flush came in the middle of the month and the September flush six weeks later, about two weeks behind time. This delay was due, in part at any rate, to the low humidity at this period. The October flush followed close on the September one although, as is usual with the later flushes, a very definite crop rise is not shown owing to the fact that shoots coming from axils low down in the bush are by this time well up into the plucking area.

Soil moisture observations made at depths down to 3½ feet show that the moisture from about 2 feet downwards does not fall much below 15 per cent. throughout the cold weather and that throughout the year the change in soil moisture in the subsoil is a steady one not subject to changes with each shower as is the moisture content of the top soil. Curves showing the change in moisture content at different depths during 1923 and 1924 are shown in Quarterly Journal, Part III 1924, p. 168.

In the middle of October the humidity was exceptionally high and a good finish to the season was assured.

Referring to temperatures, it will be recognised that the maximum or minimum, or mean temperatures only give an approximation to the temperature over a certain period. This is very noticeable so far as our bodily comfort is concerned for we often observe that after a particularly trying period the maxima and minima are below or equal to values shown by cooler periods. It was then thought that the true average monthly temperature would show some distinct difference and this has been calculated from the actual temperatures recorded at two-hour intervals throughout the year. These values are given for 1923 and 1924 with exception of May and June in the former year when the recording instrument was out of order.

healthy bark produces a callus round the edges of the diseased portion and in some cases completely covers it. The healing over of the diseased portion does not mean that the disease producing fungus has been overcome. It continues to grow in the wood and comes to the surface again below the earlier injury causing another patch of bark to die. In time the whole of one side of a branch may be diseased and white ants, saprophytic fungi etc., eat away the wood and bark which has been killed by the fungus leaving a long wound edged by thick ridges of callus. So far this description would fit the effects of a number of fungi *e.g., Macrophoma theicola,* Petch but the fructifications are quite distinct. The fructifications are produced in large numbers embedded in the dead bark. To the naked eye they merely appear as black specks. The investigation of this fungus is being continued. Observations have shown that it is able to attack woody stems which have been weakened by other causes, irrespective of the presence of wounds or dead snags. See plate.

Fungi that can be treated by spraying.

Thread blight :—There are very many bushes attacked by this disease. There are however more bushes attacked by the various species of *Corticium* mentioned below.

Corticium Spp.:—Two species of this genus were found respects the Pink disease of rubber. In all there appears to on tea stems in this district. One of these resembled in some be five distinct species of *Corticium* attacking tea in North East India. They are still under investigation at present. In general these fungi produce a film of mycelium on the bark of the plant. In some species the leaves are also attacked. None of the fungi of this genus appear to kill the branches outright but they certainly weaken them thus rendering them more susceptible to the attacks of other parasites (*e.g.*, Red rust).

White stem blight :—Another fungus resembling *Corticium sp.* in appearance has recently appeared. This fungus is not wholly external but it is however confined to the outer layers of the tissues. A branch attacked by this fungus becomes quite

white. The fungus appears to check the growth to some extent but like the *Corticium spp.* does not kill the stems.

Cankered Stems following Mosquito Blight.

Another stem disease was prevalent on sections which had been cut back or collar-pruned and subsequently badly attacked by mosquito blight. Many new shoots were covered with cankerous growths resembling those produced on vigorous tea after severe hail damage. In some cases these growths were not associated with any parasitic organisms. They were the result of the reduction of the green shoots by the mosquito. We were able to reproduce a similar condition on a vigorous growing plant at Tocklai by removing each bud and leaf from the one year old branches as fast as they appeared. The branches concerned were free from disease and yet produced the characteristic warty appearance. In most cases however under ordinary conditions such branches become infected with parasitic organisms. The commonest is Red rust. *Pestalozzia theæ,* the fungus which causes Grey blight, is also commonly found on the bark beneath the callosities.

Experience has shown that such cankered stems if left unattended seldom recover and it is wise to cut them back to about eight inches. This removes most of the cankered growth and at the same time is conducive to the widening of the bush.

The Causes of Stem Disease.

The variety of the fungi which attack tea stems in Cachar indicates that the fungi are secondary and that there are conditions, common to most of the gardens, conducive to attacks of stem disease-producing fungi. It is obvious that it is not a case of gradual dissemination of particular fungi from infecting centres.

Climate. The district has suffered from drought for three successive cold weathers. This has undoubtedly weakened the bushes. Wounds, which under ordinary circumstances seal themselves readily remain open to attack for a longer period if the soil and air moisture are deficient. The lack of moisture by lowering the general tone of the plants renders them more sus-

Table showing temperatures at Tocklai averaged for two hourly periods.

Year	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1923	64	65	72	77	.....	.....	85	86	84	82	76	68
1924	63	63	75	79	80	86	85	84	81	82	73	65

These results may be compared with the mean temperatures obtained from the maxima and minima over the same period.

Table showing the monthly mean temperatures at Tocklai.

Year	Jan.	Feb.	Mar.	Apl.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1923	61	64	74	76	79	82	83	84	81	77	70	62
1924	60	65	73	75	78	85	83	84	83	80	70	64

It will be seen that there is little difference between the values shown in the two tables.

The temperature is of importance to the tea planter in that, within limits, it determines the flushing period. With an average temperature of about 86°F it takes thirty days for a shoot of two leaves and a bud to form an axil. Within strict limits the law of Van't Hoff may be applied to the rate of growth of the flush. Briefly this law states that for each 18°F rise in temperature the speed of a chemical reaction is doubled and for a fall in temperature the reaction is similarly slowed up. On these lines the flushing period at a temperature of 68°F (*i.e.*, 86°—18°) should be sixty days whilst at 77°F (*i.e.*, 86° —9°) it should be 45 days. This fits in with experience for the flushing period in the Autumn is about six weeks.

The New Instruments at Tocklai.

Early in the year the observatory at Tocklai was moved from its old site to one about 100 yards away and several new instruments were added. The change was necessitated by the erection of buildings near the old site.

During the year an anemometer was erected on a 20 feet tower and from April onwards the wind direction and daily wind-

age was observed. In April and May the wind blew mainly from the north with a daily windage of about 50 miles. During the monsoon the direction of the ground wind was from all points of the compass although the general drift as demonstrated by the clouds was practically always from the south-west. As the season advanced the wind decreased till in December it has fallen to about 10 miles a day. During the cold season a turn of the wind to a southerly direction is accompanied by a rise in temperature and a possibility of rain.

A helio-chronometer has been placed in our new observatory and we are now in a position to give the time, no small boon in a tea district where " the time " varies on every garden.

A recording barometer has been in use for the greater part of the year. The bi-diurnal variation is about 4 millibars in the forenoon and about one millibar at night. No sharp variations have been observed so far for the hurricanes which usually blow in the early part of the year did not put in an appearance. The general variation in barometric pressure throughout the year was small. In June and July the lowest values were recorded, about 29.3 inches, after which there was a steady rise to about 29.8 inches in December.

Solar and terrestrial radiation thermometers have now been added to our instruments. The solar radiation reached its highest in August when the maximum temperature in the sun rose to 146°F. In January the average solar radiation is 110°F. The terrestrial or nocturnal radiation varies from 48°F in January to about 74°F during July, August and September.

SOME OBSERVATIONS ON STEM DISEASES IN CACHAR.

BY

A. C. TUNSTALL

Three successive droughts have caused a considerable increase in the stem diseases prevalent in the Surma Valley. A considerable number of specimens have been received at Tocklai. In order to supplement the investigations carried out in the laboratory by observations in the field the writer recently made a short tour in Cachar.

The following fungi were observed to be causing stem disease in Cachar.

FUNGI THAT REQUIRE CUTTING OUT.

Auricularia auricula-judiæ. (L.) Schr.—Jew's ear fungus :—This is one of the commonest causes of infection in the case of dead snags. The fungus first of all lives for some time in the dead wood. It then spreads downwards to the living stems attacking both the wood and the bark. The latter cracks and wrinkles and the wood becomes soft and rotten. The result is a nasty rotting wound. During the cold weather as a rule no fructifications are present but during the rains soft gelatinous brackets form. The general appearance of these resembles that of brown human ears. The spores are produced on the surface of these brackets. The size of the brackets vary from half an inch to three inches across. This fungus is more commonly found on the larger snags such as those produced on moribund centre stems.

Nectria cinnabarina. (Tode) Fr :—This fungus is also very commonly found but unlike the Jew's ear fungus it usually commences operations on the smaller twigs killing them and spreading thence to the larger branches. This fungus does not always

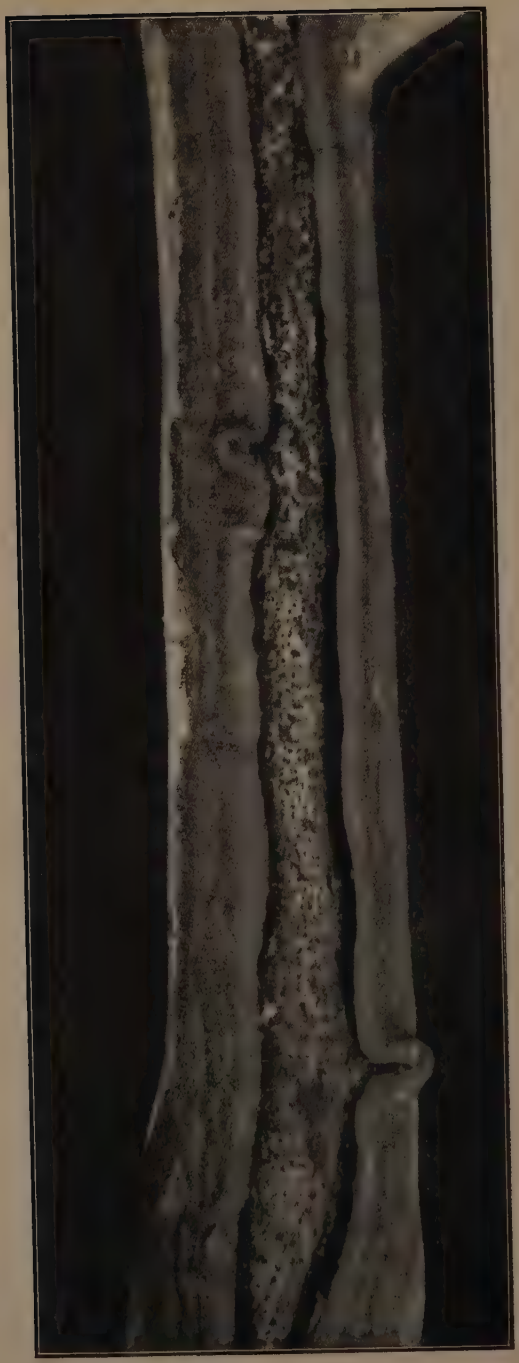
cause the bark to split and form cankerous growths. It very often merely causes the infected branches to die back. The fungus produces its fructifications in the rains. The fruits are of two kinds, small pink cushions and little groups of tiny dark red spheres. These two kinds are often produced side by side on the bark of the dead stems. There is a third kind of fruit produced also. The pink and red fruits must not be confused with those of other fungi. A fungus fructification very similar in appearance is produced on the leaves and small twigs by a fungus which feeds on scale insects. This fungus is a species of *Aschersonia*. Another common fungus often found on dead bark may possibly be confused with *Nectria* on account of its colour. The fruits of this fungus are however quite different in shape resembling pin heads about one hundred times larger than those produced by Red rust. This fungus is called *Stilbum nanum*.

Marasmius pulcher B & Br :—This fungus is to be found on a large number of bushes. It resembles Thread blight in appearance but does not appear to damage the leaves so much as the true Thread blight. It does however attack the smaller branches causing them to die back. The fructifications are sometimes found on small dead snags and in collections of dead leaves. The fungus does not appear to cause serious damage.

Marasmius equicrinis Mull :—Horse hair blight. This fungus is common on the bark of bushes attacked by other stem diseases. As a rule it merely feeds on the dead bark but on occasion it has been found penetrating living stems.

Poria hypobrunnea Petch :—One of the commonest causes of dying back from dead snags is an attack of this fungus. In most cases this fungus confines itself to the stems but on occasion it reaches the roots and continues to grow on them. The fungus forms a characteristic fruit. It is a yellowish to fawn coloured incrustation covered with minute holes.

A new disease :—The commonest of the stem disease producing fungi in Cachar is one which has only recently been observed. The fungus attacks the woody stems causing portions of it to die. The dead bark does not fall off but the surrounding



A Diseased Tea Stem.

Pages 39-40 are misplaced & are after p. 36

ceptible to disease. The hot steamy weather of the rainy seasons which succeeded the droughts is specially suitable for the growth of many of the fungi concerned. The fungi respond to the influence of climate more quickly than the tea plant and are able to take immediate advantage of the latter's weakened condition.

Soil. Class of soil alone was not responsible as badly infected tea was to be found on both bheel and teela. It was however obvious that the diseases were less apparent on sections which had been scientifically manured.

Shade and aspect seemed to have little influence except in the case of diseases like Thread blight.

Animal parasites. Except in one condition mentioned above it would appear that animal parasites such as mosquito blight and white ants cannot be held responsible fo the increase in stem disease. In the case of white ants their attack is more often the result than the cause of disease. On many sections it is probable that these annoying pests have done very useful work in removing masses of infected material.

Pruning. The very striking difference between sections severely attacked and those which had escaped was the style of pruning. In Cachar and in fact in the Surma Valley generally there are large areas of tea bushes which have been pruned for many years by the simple and cheap process of cutting straight across the tops of the bushes. This system may have been successful with plants which are naturally bushy, such as China plants, but it is obviously bad for other jats of tea. The better jat tea plants are naturally trees and as such tend to grow up in the centre. If the natural tendency is not checked the centres become a congested mass of stems which on account of the congestion become moribund. New shoots arise lower down the plant and in turn add to the congestion in the centres. In the meantime some of the moribund branches invariably become diseased and on most of the bushes there is a collection of rotting snags in their centres. The diseases concerned do not confine their attentions to the dead and moribund wood but spread downwards killing branch after branch until finally the bush dies altogether.

The white ants however in many cases come into operation before this happens and clean out a good deal of the diseased tissue at the same time killing and removing many of the young shoots arising low down on the bush. For some years past on some of the more up to date gardens the policy of removing the centres of the bushes has been adopted and the tea treated in this manner is in very much better health. The mere cutting out of centres should not be the end of the process of renovation but only the beginning. The new shoots which arise from the collar should not be allowed to grow straight up for more than one year. If they are simply cut back to the general level of the bush, the bush will in time become almost as bad as before. If, however, they are cut back to about eight inches they will generally produce shoots which grow outwards. These should in turn be cut back wherever they tend to grow inwards. In this way the new shoots will increase the spread of the bush. There will always be sufficient growth to fill up the centres with plucking shoots. By careful observation it will be found possible to arrange for a succession of new shoots from the collar to replace any of the old ones as the latter become moribund or diseased. In some cases it is impossible to cut the centres out completely at one operation but by continuing the process it is often possible to remove more and more of the centre in succeeding years until none of the old wood is left. In other cases, unfortunately there are many of them, the bush has grown like a wine glass and has made no attempt to produce shoots low down. With such bushes it has been the practice to cut the side branches back almost to the main stem when the bushes become too high. This proceeding is invariably unsatisfactory and in many cases fatal. The result is a mass of weakly shoots round a central rotting snag. Such bushes can only be treated satisfactorily in one way—by collar-pruning. If the collar-pruning is carried out in the rains surprisingly few bushes die. The shoots arising from a collar-pruned bush must be pruned to induce spread just as the new wood in centred bushes. In all cases where drastic pruning is contemplated it is necessary to manure the soil scientifically before carrying it out if the best results are to be obtained.

The Treatment of Stem Diseases that require Cutting Out.

It is obvious that to remove a disease which is growing within the tissues of the plant it is necessary to cut out the diseased portion. Unfortunately where such diseases are prevalent the number of diseased snags is so great that it is quite impossible to cut them all out. The only course to be pursued in such cases is to start a pruning programme more or less on the lines indicated above and as the pruning proceeds take special care to remove all diseased wood.

To protect cuts from reinfection is of great importance. All the larger cuts should be protected by a coating of some sort to prevent infection of the cuts as far as possible. Ordinary tar is unsuitable as it is too thick and when dry comes away from the wound forming pockets which are ideal for the cultivation of parasites. Ordinary tar thinned by the addition of turpentine is also unsatisfactory as the mixture burns the bark. Naturally thin wood tar (Stockholm tar) has been found good but it appears to have no advantage over the treatment described below.

Burgundy Paste.

Dissolve 4 lbs. of copper sulphate in 1 gallon of water. (To dissolve this amount readily the copper sulphate should be powdered and enclosed in a bag which should be suspended in hot water.) Dissolve an equal weight of washing soda or half the weight of soda ash in the same quantity of water. Mix the two solutions when cold in a large vessel. Sometimes a vigorous effervescence takes place hence the need of a large mixing vessel.

This mixture if correctly prepared is somewhat acid. The slight acidity appears to favour the growth of callus. The insoluble precipitate helps to close the pores of the exposed wood and at the same time under the action of the air gradually becomes soluble and in this condition is a fungicide, effective against most of the organisms likely to cause stem disease. In arranging the manuring the application of potash should receive special attention as experience has shown that this substance tends to make the bushes less susceptible to attacks of disease.

The Treatment of Stem Diseases that can be Treated by Spraying.

For the treatment of the external parasites such as Thread blight and *Corticium spp.* and also the White stem blight, spraying with Lime sulphur solution has been found completely successful. The application of spray fluids will form the subject of a future article.